

Serial No. 10/536,706

PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re **PATENT** application of:

Applicant: Stewart E. HOOPER *et al.*

Serial No.: 10/536,706

Art Unit: 1791

Filed: January 3, 2006

Title: **METHOD OF GROWING P-TYPE GALLIUM NITRIDE THIN FILMS BY MOLECULAR BEAM EPITAXY**

Examiner: Seyed Masoud Malekzadeh

Docket No.: YAMAP0983US

**APPEAL BRIEF**

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Alexandria, VA 22313-1450

Sir:

This brief is submitted in connection with the appeal of the above-identified application. Credit card payment of the fee set forth in 37 C.F.R. § 41.20(b)(2) is made in connection herewith. If there are any additional fees resulting from this communication, please charge the same to our Deposit Account No. 18-0988, our Docket No. YAMAP0983US.

**I. Real Party in Interest**

The real party in interest in the present appeal is Sharp Kabushiki Kaisha, assignee of the present application.

**II. Related Appeals and Interferences**

Appellants, Appellants' undersigned representative, and/or the assignee of the present application are unaware of any prior or pending appeals, interferences or judicial proceedings which may be related to, directly affect or be directly affected by, or have bearing on the Board's decision in the pending appeal.

**III. Status of Claims**

Claims 1-6, 11, and 13-20 are in the instant proceeding and are pending in the application. Claims 1-6, 11, and 13-20 stand finally rejected and are the subject of this appeal. Claims 7-10, 12, and 21-23 have been previously canceled.

**IV. Status of Amendments**

No amendments to the claims or the specification have been made subsequent to the final rejections contained in the Final Office Action dated January 16, 2009.

**V. Summary of the Claimed Subject Matter**

Independent claim 1 recites a method of growing a p-type nitride semiconductor material by molecular beam epitaxy (page 1, lines 3-6; page 4, lines 16-17), the method comprising supplying bis(cyclopentadienyl)magnesium ( $\text{Cp}_2\text{Mg}$ ) during the growth process (page 4, lines 17-18; page 10, lines 25-26), and carrying out the growth process at a temperature from 920°C to 960°C so that carbon contamination caused by  $\text{Cp}_2\text{Mg}$  is reduced in the semiconductor material (page 4, lines 25-31; page 5, line 25 to page 6, line 5; page 8, line 21 to page 9, line 3; page 14, lines 26-27).

Dependent claim 2 recites a method as claimed in claim 1, wherein the nitride semiconductor material is p-type (Ga,Al)N (page 4, lines 18-19; page 6, lines 28; page 10, lines 4-5).

Dependent claim 3 recites a method as claimed in claim 1, comprising supplying ammonia gas during the growth process (page 4, lines 19-21; page 19, lines 19-22).

Dependent claim 4 recites a method as claimed in claim 1, comprising supplying ammonia gas, gallium and  $\text{Cp}_2\text{Mg}$  to a growth chamber, thereby to grow a layer of p-type GaN (page 5, lines 1-2).

Dependent claim 5 recites a method as claimed in claim 1, comprising supplying ammonia gas, aluminum, gallium and  $\text{Cp}_2\text{Mg}$  to a growth chamber, thereby to grow a layer of p-type AlGaIn (page 5, lines 2-4).

Dependent claim 6 recites a method as claimed in 1, comprising changing the supply rate of  $\text{Cp}_2\text{Mg}$  during the growth of the nitride semiconductor material (page 5, lines 9-14; page 11, lines 5-14).

Dependent claim 11 recites a method as claimed in claim 1, wherein the growth process is carried out at a temperature of at least  $950^\circ\text{C}$  (page 5, lines 29-31; page 8, lines 27-28).

Dependent claim 13 recites a method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of at least  $1 \times 10^{-9}$  mbar (page 6, lines 6-7; page 13, lines 3-4).

Dependent claim 14 recites a method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of at least  $3 \times 10^{-9}$  mbar (page 6, lines 6-7; page 12, lines 27-32).

Dependent claim 15 recites a method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of  $1 \times 10^{-7}$  mbar or below (page 6, lines 7-8; page 13, line 5).

Dependent claim 16 recites a method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of  $1.5 \times 10^{-8}$  mbar or below (page 6, lines 7-9; page 13, line 5).

Dependent claim 17 recites a method as claimed in claim 4, comprising supplying elemental gallium at a beam equivalent pressure of at least  $1 \times 10^{-8}$  mbar (page 6, lines 13-14; page 10, lines 14-16).

Dependent claim 18 recites a A method as claimed in claim 4, comprising supplying elemental gallium at a beam equivalent pressure of  $1 \times 10^{-5}$  mbar or below (page 6, lines 14-15; page 10, lines 14-16).

Dependent claim 19 recites a method as claimed in claim 5, comprising supplying elemental gallium and elemental aluminum at an overall beam equivalent pressure of at least  $1 \times 10^{-8}$  mbar (page 6, lines 17-18; page 10, lines 22-23).

Dependent claim 20 recites a method as claimed in claim 5, comprising supplying elemental gallium and elemental aluminum at an overall beam equivalent pressure of  $1 \times 10^{-5}$  mbar or below (page 6, lines 18-20; page 10, lines 22-23).

## **VI. Grounds of Rejection to be Reviewed on Appeal**

Claims 1-6, 11, and 13-18 stand rejected pursuant to 35 U.S.C. § 103(a) as being obvious over Barnes et al., U.S. Patent Application Publication No. 2004/0214412 (Barnes) in view of Mayer et al, *Journal of Crystal Growth*, 201/202 (1999) at pages 318-322 (Mayer). Claims 19-20 stand rejected pursuant to 35 U.S.C. § 103(a) as being obvious over Barnes and Mayer, and further in view of Hooper et al., U.S. Patent Application Publication No. 2002/0117103 (Hooper).

## **VII. Argument**

### **A. Overview of the Invention**

Claim 1 recites “a method of growing a p-type nitride semiconductor material by molecular beam epitaxy using bis(cyclopentadienyl) magnesium ( $\text{Cp}_2\text{Mg}$ ) during the growth process, and by ***“carrying out the growth process at a temperature from 920°C to 960°C so that carbon contamination caused by  $\text{Cp}_2\text{Mg}$  is reduced in the semiconductor material.”*** (Emphasis added.)

As stated in the application, MBE methods are superior to MOCVD methods in that MBE methods avoid the need for post-growth annealing or irradiation steps common in MOCVD methods. (See Application at page 3, line 31 to page 4, line 5; page 11, lines 16-25). Prior to the current invention, however, an MBE method employing  $\text{Cp}_2\text{Mg}$  as the magnesium source would have been **widely expected** to result in undesirable carbon contamination in the resultant semiconductor layers, and therefore  $\text{Cp}_2\text{Mg}$  was generally avoided in conventional MBE methods. (Application at page 4, lines 26-28.) Applicants have found, however, that carbon contamination is reduced by carrying out the growth process within a specific high temperature range, particularly a temperature range of 920°C to 960°C. (See Application page 4, lines 25-31; page 5, line 25 to page 6, line 5; page 8, line 21 to page 9, line 3; page 14, lines 26-27.)

The claimed invention, therefore, yields an unpredictable and unexpected result. The references cited by the Examiner, whether considered individually or in combination, do not disclose or suggest the claim features of carrying out a growth process using  $\text{Cp}_2\text{Mg}$  as the p-type dopant, at a temperature range of 920°C to 960°C, to reduce carbon contamination. Accordingly, the rejections should be overturned.

**B. Claim Rejections – 35 U.S.C. § 103(a) Based On Barnes and Mayer**

Claims 1-6, 11, and 13-18 stand rejected pursuant to 35 U.S.C. § 103(a) as being obvious over Barnes et al., U.S. Patent Application Publication No. 2004/0214412 (Barnes) in view of Mayer et al, *Journal of Crystal Growth*, 201/202 (1999) at pages 318-322 (Mayer). Barnes has been applied in multiple Office Actions and discloses an MBE process in which elemental magnesium is used as the p-type dopant material. Barnes discloses carrying out the MBE process preferably at a temperature between 850°C and 1050°C, which is broader than the claimed temperature range.

The Examiner recognizes that Barnes does not disclose the use of  $\text{Cp}_2\text{Mg}$  as a p-type dopant. Barnes also does not make any reference to issues associated with carbon combination, which follows from Barnes' use of elemental magnesium as the p-

type dopant. The Examiner, however, states that Mayer discloses such features and concludes that it would have been obvious to combine the disclosures of Barnes and Mayer to arrive at the claimed invention. Applicants traverse the rejections for at least the following reasons.

**1. *The Examiner Misinterprets Irrelevant Passages of Mayer***

Mayer describes an MBE process that appears to use  $\text{Cp}_2\text{Mg}$  as the p-type dopant material. (See Mayer at section 2 and the first paragraph of section 4.) In the Advisory Action, the Examiner states that Mayer teaches “the intensity of all bounds exciton [sic] decreases with increasing temperature, and the free excitons dominate spectra at temperatures above 29 K and at about 80 K,” citing Mayer at page 320, right column, lines 5-10. The Examiner concludes from this passage that Mayer teaches the use of  $\text{Cp}_2\text{Mg}$  as the dopant material at an unspecified “preferred temperature”. (Advisory Action at pages 3-4.) The Examiner simply is incorrect.

In fact, this passage of Mayer bears no relation to the part of the process involving  $\text{Cp}_2\text{Mg}$ . Rather, this passage relates to dissolving Mg-H complexes to produce a higher density of charge carriers. Mayer states as to this part of the process that the intensity of bound excitons decreases with increasing temperatures. Free excitons dominate the spectra at temperatures above 29°K, and at about 80°K **even the free exciton C** becomes visible (see page 320, right column, lines 5-10).

In the Final Office Action, the Examiner considered the reference in Mayer to a “free exciton C” as a direct reference to carbon contamination (“C” being the elemental symbol for carbon). The Examiner was wholly mistaken, as one skilled in the art would certainly understand. Rather, one skilled in the art would understand that an “exciton” is a term relating to an excited state of an electron that may be generated in a semiconductor material. Excitons may arise in a variety of forms, which those skilled in the art may refer to, for example, as A-excitons, B-excitons, or C-excitons. Mayer’s reference to the “free exciton C” thus has nothing to do with carbon in any sense, but rather relates to the C-type exciton.

In the Advisory Action, the Examiner incorporates this blatant error in another attempt to relate Mayer to carbon contamination. (See Advisory Action at bottom of page 3 carrying over to page 4, incorporating the Final Office Action at page 6, line 11-19.) Mayer, however, says nothing about carbon contamination, as one skilled in the art certainly would understand.

In the Advisory Action, the Examiner also relies on the cited passage of Mayer as generally disclosing the use of  $\text{Cp}_2\text{Mg}$  at a preferred temperature. In doing so, the Examiner again errs because this passage is simply irrelevant to the use of  $\text{Cp}_2\text{Mg}$  (or any other material) as the dopant.

As stated above, the referenced passage of Mayer deals with producing a higher concentration of charge carriers from dissolving Mg-H complexes. This bears no relation to the actual growth portion of the MBE process, whether using  $\text{Cp}_2\text{Mg}$  or any other dopant material (e.g., elemental magnesium). This is evident from the ***vast temperature difference (29°K-80°K)*** set forth in the referenced passage of Mayer as compared to the much higher growth process temperatures recited in the claims. In centigrade temperature units, the temperatures identified in the referenced Mayer passage would equate to about -244.15°C to -193.15°C, ***about 1200-1300 degrees colder*** than the claimed temperature range for employing  $\text{Cp}_2\text{Mg}$ . One skilled in the art, therefore, would not understand the referenced passage of Mayer, relied upon by the Examiner, as teaching anything about how to carry out the growth portion of an MBE process using  $\text{Cp}_2\text{Mg}$ .

Furthermore, with respect to growth processes Mayer discloses ***only*** that growth temperatures should be approximately 750°C (see Mayer at section 4, second paragraph). No effect of modifying this temperature is disclosed or suggested ***at all*** in Mayer, and the problem of carbon contamination is not even recognized. It follows, therefore, that Mayer cannot be understood as disclosing or suggesting that one may reduce carbon contamination by carrying out the MBE process using  $\text{Cp}_2\text{Mg}$  at the claimed temperature range.

**2.     *The Claimed Invention Is Not Obvious Over Barnes and Mayer***

As set forth in the Application, prior to the current invention an MBE method employing  $\text{Cp}_2\text{Mg}$  as the magnesium source would have been **widely expected** by those skilled in the art to result in undesirable carbon contamination in the resultant semiconductor layers. (Application at page 4, lines 26-28.) The claimed invention, therefore, produces an unexpected and unpredictable result. Specifically, carbon contamination is reduced by carrying out the growth process using  $\text{Cp}_2\text{Mg}$  within the specific high temperature range of 920°C to 960°C. Given this unexpected and unpredictable result, the claimed invention is not obvious over Barnes in view of Mayer.

In summary, Barnes discloses an MBE process that does not employ  $\text{Cp}_2\text{Mg}$  as the dopant material, and at a temperature range that is significantly broader than the claimed temperature range. Mayer discloses an MBE process that employs  $\text{Cp}_2\text{Mg}$  as the dopant material, but only at a temperature of about 750°C, well below the claimed temperature range and the temperature range of Barnes. Neither reference discloses or suggests that one may modify the temperature of the growth portion of the MBE process to reduce carbon contamination. Indeed, neither reference mentions carbon contamination at all. The claimed combination of (1) the use of  $\text{Cp}_2\text{Mg}$  as the dopant material, (2) at a specific temperature range of 920°C to 960°C, and (3) reducing carbon contamination, yields an unpredictable result that one skilled in the art would not understand or expect from a combination of Barnes and Mayer.

For at least these reasons, the claims 1-6, 11, and 13-18 are not obvious over Barnes in view of Mayer, and the rejection of these claims should be withdrawn.

**C.     *Claim Rejections – 35 U.S.C. § 103(a) Based On Barnes, Mayer, and Hooper***

Claims 19-20 stand rejected pursuant to 35 U.S.C. § 103(a) as being obvious over Barnes and Mayer, and further in view of a more tertiary reference, Hooper et al., U.S. Patent Application Publication No. 2002/0117103 (Hooper). Hooper is cited as disclosing the pressures of supplied elemental gallium and aluminum, as recited in



claims 19 and 20. Hooper does not supply the deficiencies of the combination of Barnes and Mayer, described above, and the Examiner does not indicate otherwise.

For at least these reasons, claims 19-20 also are not obvious over Barnes, Mayer, and Hooper, whether individually or in any combination thereof. Accordingly, the rejections should be overturned.

***D. Conclusion***

For at least the foregoing reasons, claims 1-6, 11, and 13-18 are not obvious over Barnes in view of Mayer, and claims 19-20 are not obvious over the combination of Barnes and Mayer further in view of Hooper. Accordingly, Appellants respectfully request reversal of the Examiner's rejections of claims 1-6, 11, and 13-20.

**VII. Claims Appendix**

An appendix containing a copy of the claims involved in this appeal is attached to this brief.

**IX. Evidence Appendix**

An evidence appendix is attached, but identifies no items of evidence.

**X. Related Proceedings Appendix**

A related proceedings appendix is attached, but identifies no decisions.

Respectfully submitted,

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Serial No.: 10/536,706

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**CLAIMS APPENDIX**

1. A method of growing a p-type nitride semiconductor material by molecular beam epitaxy, the method comprising supplying bis(cyclopentadienyl)magnesium ( $\text{Cp}_2\text{Mg}$ ) during the growth process, and carrying out the growth process at a temperature from  $920^\circ\text{C}$  to  $960^\circ\text{C}$  so that carbon contamination caused by  $\text{Cp}_2\text{Mg}$  is reduced in the semiconductor material.
2. A method as claimed in claim 1, wherein the nitride semiconductor material is p-type (Ga,Al)N.
3. A method as claimed in claim 1, comprising supplying ammonia gas during the growth process.
4. A method as claimed in claim 1, comprising supplying ammonia gas, gallium and  $\text{Cp}_2\text{Mg}$  to a growth chamber, thereby to grow a layer of p-type GaN.
5. A method as claimed in claim 1, comprising supplying ammonia gas, aluminum, gallium and  $\text{Cp}_2\text{Mg}$  to a growth chamber, thereby to grow a layer of p-type AlGaN.
6. A method as claimed in 1, comprising changing the supply rate of  $\text{Cp}_2\text{Mg}$  during the growth of the nitride semiconductor material.
11. A method as claimed in claim 1, wherein the growth process is carried out at a temperature of at least  $950^\circ\text{C}$ .
13. A method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of at least  $1 \times 10^{-9}$  mbar.

14. A method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of at least  $3 \times 10^{-9}$  mbar.
15. A method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of  $1 \times 10^{-7}$  mbar or below.
16. A method as claimed in claim 1, comprising supplying  $\text{Cp}_2\text{Mg}$  at a beam equivalent pressure of  $1.5 \times 10^{-8}$  mbar or below.
17. A method as claimed in claim 4, comprising supplying elemental gallium at a beam equivalent pressure of at least  $1 \times 10^{-8}$  mbar.
18. A method as claimed in claim 4, comprising supplying elemental gallium at a beam equivalent pressure of  $1 \times 10^{-5}$  mbar or below.
19. A method as claimed in claim 5, comprising supplying elemental gallium and elemental aluminum at an overall beam equivalent pressure of at least  $1 \times 10^{-8}$  mbar.
20. A method as claimed in claim 5, comprising supplying elemental gallium and elemental aluminum at an overall beam equivalent pressure of  $1 \times 10^{-5}$  mbar or below.

**EVIDENCE APPENDIX**

None.

**RELATED PROCEEDINGS APPENDIX**

None.